Journal of the Royal Society of Western Australia, Vol. 60, Part 2, 1978, p.33-40.

A sedimentological study of Devil's Lair, Western Australia

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Manuscript received 22 February 1977; accepted 22 March 1977

Abstract

The sediments in Devil's Lair cave, Western Australia, show a complex sequence of depositional and diagenetic events. Most of the clastic sediments are derived from weathered aeolianite. The main feature of the cave sediments is their textural uniformity, seemingly independent of microclimatic variations; this is inherited from the aeolianite source rock. The clastic sediments are interbedded with complex flowstone layers, formed during sedimentation pauses related to changes of the cave entrance, and are lithified through carbonate cementation. Human or animal activity had little influence on either the composition or the diagenesis of the cave sediments.

Introduction

Devil's Lair is a small cave about 5 km from the sea in Quaternary aeolianite in the Cape Leeuwin-Cape Naturaliste region of the extreme southwest of Australia (Fig. 1). The cave deposits have recently been excavated by members of the staff of the Western Australian Museum, leading to a series of important archaeological and biotic finds which are summarised in the works of Dortch (1974), Dortch and Merrilees (1972, 1973), and Baynes, Merrilees and Porter (1976). The writer studied samples from the 1970 excavations and collected further samples during a visit in April 1974.

General setting

Geology

Devil's Lair cave was formed in the calcareous aeolianite (Tamala Eolianite) capping the Precambrian crystalline rocks that form the Leeuwin-Naturaliste ridge. The mostly lithified dune deposits occur at elevations of up to 230 m, and their distribution is shown in Fig. 1. Although the aeolianite is predominantly a limestone, the calcium carbonate content ranges from 10% to 90%. The calcareous particles consist of sponge spicules, fragments of mollusc shells, calcareous algae and foraminifera. The remainder of the rock consists of quartz, feldspar and heavy minerals. The older dune deposits are cemented by calcium carbonate. Caves are developed in the lithified dunes and these are generally found on the leeward side of the ridge, possibly formed by solution processes acting below the water table (Bastian 1964). The cave systems are complex and interconnecting, and many open out of dolines, as in the case of Devil's Lair and Nannup Cave, which open from the same doline.

Soils

The soil pattern of the coastal dunes varies with erratic and variable segregation within the parent material as a result of leaching, the dominant pedogenetic process. They generally have a superficial layer of dark brown loamy sand, containing some organic matter and seldom more than 6 cm thick, which overlies 6-42 cm of dark brown sand with a little clay, and a further 6 cm of brown sand over the

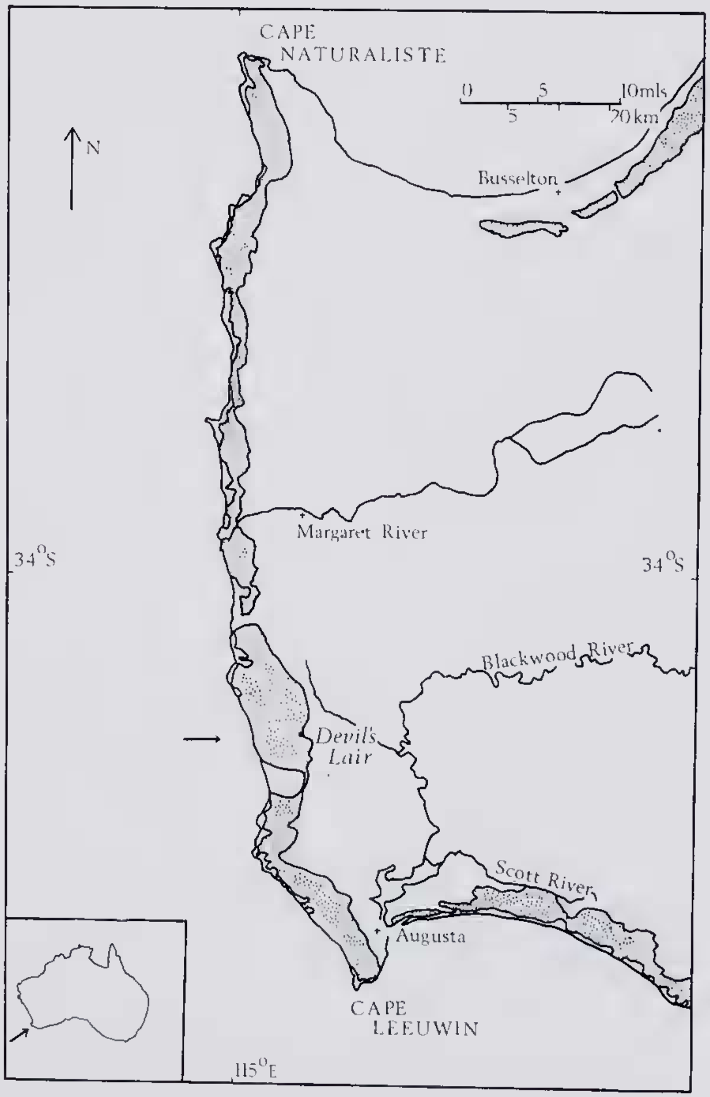

Figure 1.—The Cape Leeuwin-Cape Naturaliste region of Western Australia, showing the location of Devil's Lair. The shaded area represents the approximate distribution of the Tamala Eolianite. Modified from Lowry (1967).

limestone cap rock. Lumps, nodules and bands of ferruginous material are common, and such soils present a marked contrast to the acid podsols which develop further inland.

Climate and vegetation

At present the vicinity of the cave has a high annual rainfall of 910-1 520 mm, falling in the winter months, and the vegetation is an open Karri forest (*Eucalyptus diversicolor*) with an understorey including Peppermint (*Agonis flexuosa*). Low woodland, scrub and open heath occur nearer to the coast.

Cave morphology

The cave consists of a single chamber, irregular in shape, with two separate entrances, one of which (the northern) is now blocked by a talus cone composed of clastic deposits and flowstone (see Fig. 2). The southern entrance is the present means of access, but the slope of the strata suggests that it was not open during most of the depositional history of the cave, and that the greater part of the sediments entered from the north.

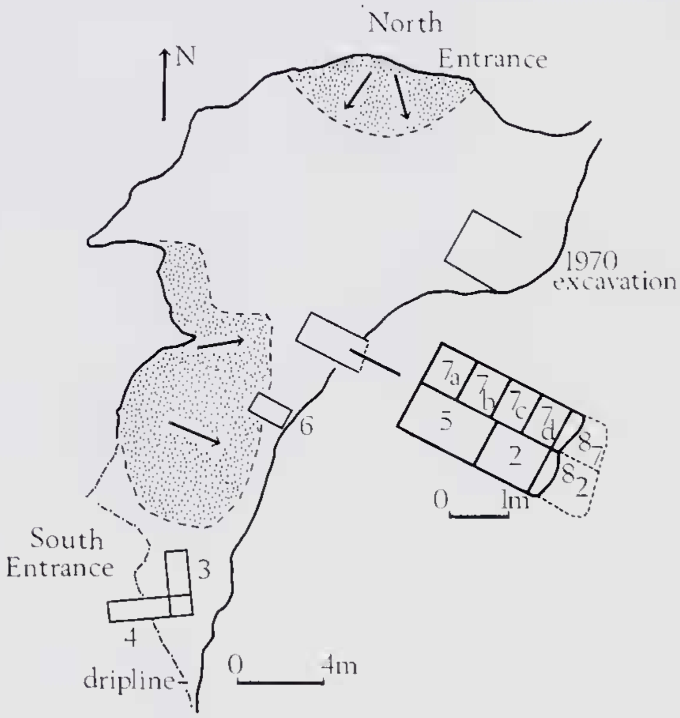

Figure 2.—Sketch plan of the cave floor of Devil's Lair, showing the location of excavation trenches. The shaded areas indicate the approximate extent of the main talus cones.

The floor of the cave is mainly covered by a sheet of flowstone of irregular thickness. Active speleothem formation continues and water still enters the cave through crevices. Cave temperature remains relatively constant and light penetrates into the cave, with the exception of the extreme rear (northern area), more than 15 m from the present entrance.

Clastic sediments

The sediments consist of interbedded sand, flowstone and stalagmite, together with lithified bands and occupation horizons. In places they have been disturbed by animal activity, and the occasional occupation by human groups is evidenced by the presence of hearths and pits. Nonclastic material includes bone, artifacts, charcoal and other biotic remains. The maximum thickness of the sediments is in excess of the 4 m established in the excavation. A radiocarbon date from immediately below the uppermost flowstone which seals the deposits indicates the end of clastic sedimentation shortly before 6490 ± 145 BP. The oldest samples are probably older than 30 000 BP.

Analytical procedures

Trenches 2, 5, 7 a-d, 8 (2) and 8 (7) (Fig 2) were sampled in 1974 for laboratory analysis, together with samples from Trench A1 which were collected in 1971. Dry sieve analysis, grain surface texture studies and determination of chemical composition were carried out in the laboratory (Shackley 1975) to complement the field data. Field observations focussed on description of composition, colour, texture, cementation and compaction. Field tests for pH, phosphates and humus were also carried out.

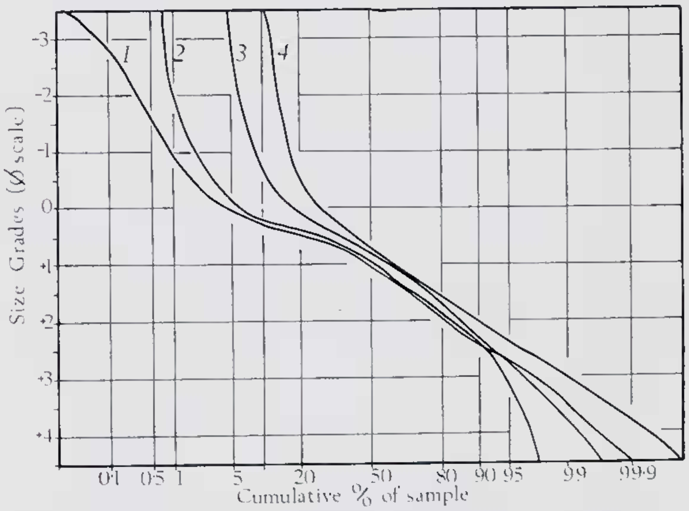

Figure 3.—Particle size distribution curves, plotted on arithmetic probability paper, for samples from Devil's Lair. 1—Low orange brown earthy layer, Trench 6. 2—Middle orange brown earthy layer, Trench 6. 3—High orange brown earthy layer, Trench 6. 4—Trench 6, top first orange brown earthy layer.

Composition

Thirty samples of the clastic sediments, taken from different trenches, were subjected, after decalcification, to a detailed particle size analysis by dry sieving. Table 1 shows that the sediments consist chiefly of rather poorly-sorted gravelly quartz sands, generally positively skewed and leptokurtic. The proportion of mud (silt and clay) in the samples was very low, only 4 samples containing more than 5%. Fourteen

Table 1.

Particle size analysis, Devil's Lair sediments.

Source of Sample	Approx. depth (cm. below cave datum)	Weight processed (g)	Composition			Descriptive Parameters				Textural Description (Folk 1954)
			Gravel (%)	Sand (%)	Mud (%)	Mean (ϕ)	Standard Deviation	Skewness	Kurtosis	
Topsoil outside cave	(above)	878·2	20·5	73·4	5·9	0·69	2·00	0·29	1·06	Gravelly sand, moderately sorted, mesokurtic
Tr 7c, 'Dark earthy layer'	75	1 645·0	13·7	85·4	0·7	0·78	1·42	–0·18	1·62	Gravelly sand, poorly sorted, very leptokurtic
Tr.5, 'dark earthy layer'	60	845·0	3·9	89·9	6·1	1·35	1·48	0·32	1·17	Gravelly sand, moderately sorted, mesokurtic
Tr.5 'earthy' band in 'flowstone complex'	80	1 230·0	3·7	95·6	0·5	1·07	1·04	–0·29	0·99	Slightly gravelly sand, poorly sorted, mesokurtic
Tr.5, 'first orange brown earthy layer'	150	1 289·0	0·4	99·4	0·0	1·13	0·97	0·36	0·84	Slightly gravelly sand, moderately poorly sorted, platykurtic
Tr.5, 'light earthy layer'	220	1 108·0	6·4	92·8	0·7	0·78	1·01	0·03	1·66	Gravelly sand, poorly sorted, mesokurtic
Tr.5, 'second orange brown earthy layer'	240	1 087·0	1·1	97·9	0·9	1·10	0·90	0·35	0·99	Slightly gravelly sand, moderately poorly sorted, mesokurtic
Tr.6, stratigraphic position uncertain	?	458·0	13·1	80·1	6·7	1·09	1·69	0·23	1·18	Gravelly sand, moderately sorted, mesokurtic
Tr.6, stratigraphic position uncertain	?	1 197·0	4·3	95·4	0·2	0·99	0·99	0·27	0·94	Slightly gravelly sand, moderately poorly sorted, mesokurtic
Tr.6 cave pearl and bone layer	110	487·0	53·3	45·9	0·6	–0·84	2·14	0·24	0·78	Sandy gravel, very poorly sorted, platykurtic
Tr.6, Hearth 1	120	390·0	6·1	91·0	2·8	1·13	2·27	0·18	1·33	Gravelly sand, poorly sorted, leptokurtic
Tr.6, 'brownish earthy layer'	150	1 615·0	0·8	98·7	0·3	1·12	0·90	0·32	0·86	Slightly gravelly sand, moderately poorly sorted, platykurtic
Tr.6, 'brownish earthy layer'	200	2 225·0	1·9	94·9	3·1	1·06	0·91	0·20	1·25	Slightly gravelly sand, moderately poorly sorted, leptokurtic
Tr.6, 'brownish earthy layer'	250	1 427·0	9·6	89·8	0·5	0·95	1·49	0·15	1·69	Gravelly sand, poorly sorted, leptokurtic
Tr.8 ? Hearth 2 ?	?	1 423·0	17·2	82·6	0·0	0·34	1·44	–0·41	1·45	Gravelly sand, poorly sorted, very leptokurtic
Tr.A1, Grey 'Ashy' lens	105	501·0	26·0	73·7	0·1	0·38	1·65	0·30	0·66	Gravelly sand, poorly sorted, platykurtic
Tr.A 1, 'rubbly layer'	110	221·2	39·9	57·7	2·3	0·15	1·67	–0·12	0·68	Sandy gravel, poorly sorted, platykurtic
Tr.A 1, 'earthy layer'	130	1 216·0	3·3	94·7	1·8	1·03	0·94	0·21	1·14	Slightly gravelly sand, moderately sorted, leptokurtic
Tr. A 1, 'rubbly layer'	152	1 396·0	2·7	94·5	2·6	1·18	1·07	0·15	1·18	Slightly gravelly sand, moderately poorly sorted, leptokurtic
Tr. A 1 'earthy layer'	170	1 245·6	8·1	89·7	2·1	1·10	1·29	0·10	1·63	Gravelly sand, poorly sorted, leptokurtic
Tr. A 1, 'rubbly layer'	230	1 504·2	19·8	79·6	0·5	0·21	1·58	0·01	1·07	Gravelly sand, poorly sorted, mesokurtic
Tr. A 1, 'thin flowstone'	234	707·3	1·6	94·0	4·2	1·12	1·16	0·27	1·40	Slightly gravelly sand, poorly sorted, leptokurtic
Tr. A 1, 'earthy layer'	235	252·3	17·5	79·1	3·2	0·57	1·77	0·09	1·43	Gravelly sand, moderately poorly sorted, leptokurtic
Tr. A 1, 'dark earthy layer'	250	1 178·7	4·7	94·5	0·7	1·02	1·08	0·09	1·39	Slightly gravelly sand, moderately poorly sorted, leptokurtic
Tr. A 1, 'light sandy layer'	264	2 797·4	15·8	76·0	8·1	1·44	2·03	0·14	1·03	Gravelly sand, moderately sorted, mesokurtic
Tr. A 1, 'earthy layer with thin sheets of flowstone	280	851·4	4·8	84·3	0·8	0·78	1·54	0·26	0·87	Gravelly sand, poorly sorted, platykurtic
Tr. A 1, 'banded earthy layer'	288	1 610·6	1·3	97·3	1·2	0·90	0·80	0·39	1·60	Slightly gravelly sand, moderately sorted, very leptokurtic
Tr. A 1, 'banded earthy layer'	300	1 023·4	3·7	94·1	2·1	1·14	1·06	1·25	1·13	Slightly gravelly sand, poorly sorted, leptokurtic
Tr. A 1, stratigraphic position uncertain	?	1 465·6	19·3	79·1	1·4	0·17	1·53	0·03	1·40	Gravelly sand, poorly sorted, leptokurtic

samples contained more than 90% and 26 samples more than 75% sand, but only 1 sample had more than 50% gravel. Some particle size distribution curves (Fig. 3) illustrate the unimodal nature of the sediments, the bulk of which consist of particles of grain sizes 0.5-1.5 ϕ (coarse/medium sand). The Inclusive Graphic Statistics of Folk and Ward (1957) were calculated for each sample using the computer program SIEVETTE (Shackley 1975) and are also listed in Table 1. They show the mean grain size of the sediments to be 1.17 ϕ (medium sand), and that the skewness values tend on the whole to be positive. However, the existence of 4 samples with negative skewness values is interesting, since this feature has been taken by many workers (for example Friedman 1961) as typical of beach sands.

The most important result of this analysis is to emphasise the striking uniformity of the deposits, which are composed of sand of very similar textural composition. This is an unusual feature of cave deposits which, since they are formed under rather complex sedimentological conditions, tend towards greater variety. It seems unlikely that the results of this analysis can be of any value in detecting definite trends, or in defining stratigraphic horizons. Minor textural differences are principally attributable to variations in the amount of coarser clastic particles weathered from the cave walls, and to later disturbance, and no palaeoenvironmental evidence of value can be deduced from these results. The sediments are mostly consolidated and the baulks of the trenches need no supports. Thin section study combined with treatment by hydrochloric acid showed that this consolidation was due to a calcite cement.

Origin

The cave sediments could either be derived from weathering of the aeolianite inside the cave or from material weathered outside the cave and redeposited. In either case the primary source is the aeolianite but the weathering products have been mixed with organic matter and humus from exterior topsoil, together with the debris of human and animal occupation. The source material controls to a large extent the nature of the weathering products, and in this case the cave sediments directly reflect the composition of the aeolianite.

The cave deposits have been subjected to some degree of diagenesis, including the formation of speleothems and gypsum. Their characteristics therefore depend on the textural and mineralogical characteristics of the lithified dune and beach sands, subsequent weathering, transport, and renewed diagenesis. These features and processes are related to climate, but the nature of the resulting sediments suggests that it was not the controlling factor, a situation quite contrary to that generally found in European caves.

The stages in the formation of the deposit are shown diagrammatically in Fig. 4. The sediments in question bear many relict features from previous stages in the cycle, for example the negative skewness values of some layers of sediment, which seem likely to be related to the original composition of aeolianite.

At present the primary sedimentological process operating within the cave is the deposition of calcium carbonate as a cementing agent, but very little active weathering occurs. It is therefore difficult to envisage the production of the deposit *in situ* as the exclusive product of weathering under a different climatic regime. It also seems unlikely that local macroclimate greatly influences the microclimate of the cave, certainly not enough to produce this type and depth of deposit.

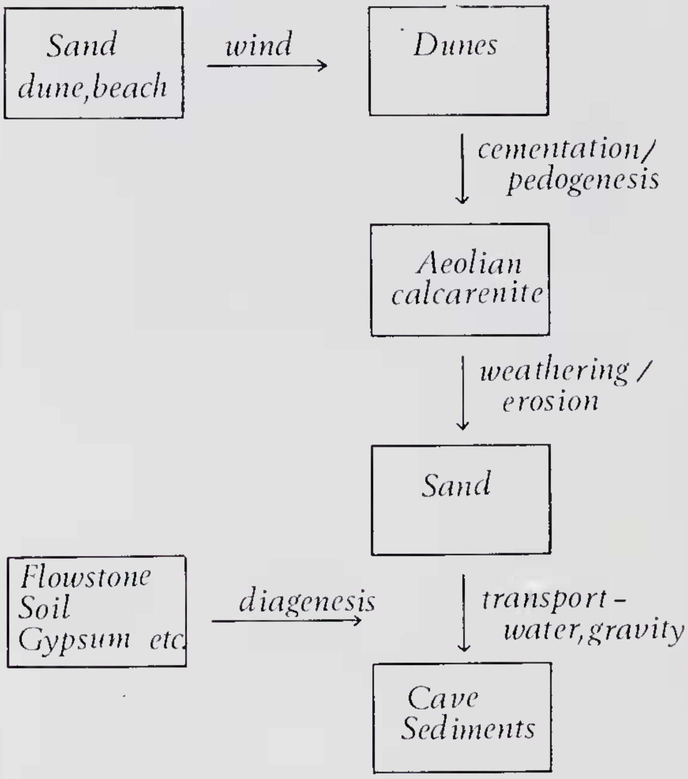

Figure 4.—Flow diagram indicating the processes which have contributed to the formation of the Devil's Lair sediments.

This suggests that the deposits were derived from material weathered from the aeolianite *outside* the cave, and redeposited inside, via the north entrance. The nature of the material and of the cave entrance suggest that wind was not the transporting medium, and it is suggested that the material either arrived in water-transported 'bursts', as suggested by Dortch and Merrilees (1973) as a result of especially heavy rainfall, or that it arrived as a continuous slow trickle.

If sediment had accumulated on the surface during the dry season and was then washed into the cave during the rainy season, one would expect more systematic laminations and a greater variation in the nature of the sediments. Laminae were, however, more obvious in Trench 9 (nearer the cave wall) than in

Trench 5, at the same stratigraphic levels. However, the lack of more extensive laminae does not necessarily negate the 'burst' sedimentation theory, since there seems to be no sedimentological process which could produce such a very slow rate of accumulation, less than 1 mm per year, if it were continuous.

An examination of the surface textures of the cave sediments shows them to be identical to those of the aeolianite, although showing evidence of many different sedimentological processes, and there seems to be no doubt that this was the source material. The composition of the topmost ('dark earthy') layer is rather different, and it has a high clay and humus content, which suggests that it was primarily derived from topsoil, washed into the cave from the south entrance after the north entrance became sealed by the talus cone.

The very slow rate of accumulation is indeed remarkable, and was commented on by Lundelius (1960) as well as by later workers. Dortch and Merrilees (1972) consider that the rapid burial of a prominent stalagmite indicates a fast rate of deposition for the upper part of the deposit, and they suggest that accumulation of sediment in the cave was not slow, but intermittent. The writer agrees with this.

A series of samples taken from depths of 320, 250 and 200 cm below cave datum in Trench 8_2 which would span the maximum cold of the last glaciation (the period 23 000-16 000 BP) show no appreciable variations. If the variations in the sedimentation pattern of the cave had been attributable to climatic fluctuations then it would be expected that these samples would show considerable differences. Analysis showed them to be similar in colour, phosphate and humus content, as well as in particle size. No variation in grain surface texture could be observed under the microscope and the conclusion was drawn that either there had been no major climatic change or that the cave sedimentation was independent of macroclimate. The period covered by these samples would be included in the major recorded fall in sea level between 40 000-15 000 BP, but it has been suggested that local climate did not change drastically during this period. However, it would seem that climate had little influence over the sedimentation pattern, unless increased rainfall at any period stimulated more sedimentation 'bursts'. This might well have happened in the upper part of the deposits.

A study of the faunal changes in Devil's Lair (Baynes, Merrilees and Porter 1976) suggests the possibility of an alteration in the position of the forest zone near Devil's Lair, perhaps related to a glacioeustatic rise in sea level. It seems probable that some time after 19 000 BP the sea west of the cave fell at least 100 m below its present level, and then began to rise again, reaching a level of –40 m by 12 000 BP and its present level some time during the postglacial (Baynes, Merrilees and Porter 1976). It is clear then that the deposition of the 'first orange brown earthy layer', bounded by a radiocarbon date of 19 000 BP at the base and 12 000 BP at the top, must have taken place during a period of marked palaeoenvironmental change. Bearing in mind that at some time during this period the sea would have been as much as 20 km further away from the site than at present, and that climate, weathering and erosional processes must inevitably have fluctuated, one can say that the uniformity of the deposits must indicate independence of climatic control.

Flowstone horizons

Composition

Two distinct varieties of speleothems are present in Devil's Lair, discrete stratified flowstone layers occurring approximately parallel to the surface of the floor on which they are formed, and secondary calcitic penetration of the clastic sediments. In addition to these forms, individual stalagmites occur, such as the one figured by Dortch and Merrilees (1972). Many of the flowstone layers in the cave are rather thin, of the order of 1 cm in thickness. The flowstone levels seem often to be associated with quantities of charcoal, sometimes included within them and sometimes occurring as charcoal rich bands immediately underneath. Although the flowstones consist mainly of calcite precipitate they may also contain quantities of clastic deposits, but there are sharp boundaries with the overlying clastic layers; they are composed of large ($>$ 0.02 mm) clear, elongated crystals whose long axes occur perpendicular to the precipitating surface.

Formation

Calcitic flowstones are formed by the precipitation of calcite from thin films of water. However, only a small quantity of water is required and this can be met with under a variety of climatic conditions. There is no close relationship between flowstone formation and climatic control, although it is a common assumption that the deposition of flowstone layers represents a wet episode should a large quantity of water be required. Two main factors seem to control the formation of flowstone layers, the most important being the rate and continuity of clastic sedimentation, and secondly, and to a lesser extent, fluctuations in surface climate which produce changes in vegetation and thus changes in the amount of carbon dioxide which is dissolved in the groundwater.

Frank (1973) noted that the rates of clastic alluviation in caves, particularly in entrance facies, far exceed the precipitation rate of calcite, and may even be deposited 7 times as fast as stalagmite could possibly accumulate. This is important for Devil's Lair, where it is suggested that the majority of the clastic material entered the cave very fast indeed, as 'bursts', which were intermittent and resulted in an overall slow rate of sedimentation. Thus it would clearly have been impossible for flowstones to have developed during a sedimentation 'burst', irrespective of the amount of ground water available.

Kukla and Lozek (1958), working on similar problems, concluded that the presence of flowstones in a clastic sequence indicated a slowing down or a complete cessation of clastic deposition. It is therefore clear that whatever the climatic fluctuations the flowstone layers within the cave mark periods of pauses in sedimentation, and must also mark periods when the cave was not being utilised either by animal or human groups, since this would have necessitated an open entrance which would have permitted sediment accretion. It is unlikely that extensive deposits of flowstone could have formed while the entrance was open. This does not preclude the inclusion of biotic or archaeological remains within the flowstone, since as flowstone deposition was rather slow it is inevitable that even the action of gravity would result in some debris becoming incorporated into the layers, or flowstone would accumulate round objects protruding from the general surface.

Butzer (1971) stated that a sub-humid moisture regime and a temperate climate is optimum for speleothem formation. Corbel (1952, 1959, 1961) estimated that when the mean annual temperature is greater than 18°C and the mean annual rainfall exceeds 1 000 mm speleothems would form in all parts of a cave. The present climate around Devil's Lair is far milder than these limits, but the cave interior is still rather damp, with calcareous solutions dripping inside the cave during the wetter months. Speleothem formation is still continuing at the present day, although not resulting in continuous flowstone layers.

It is possible (Baynes, Merrilees and Porter, 1976) that both temperature and quantity of rainfall may have increased between 19 000 and 12 000 BP, and that this may have had some effect on the deposition of the upper flowstones. However, the solution and precipitation of calcite is not only dependent on temperature and rainfall, but is also a function of the availability of carbon dioxide, so that the control is indirect since it is the surface vegetation and soil microorganisms which control carbon dioxide availability. Schmid (1958, 1963) and Kukla (1961) maintain that speleothem growth is enhanced by warm humid climates where there are substantial amounts of surface vegetation to provide the carbon dioxide for the solution of calcite, and then enable calcite-laden water to precipitate the mineral after entering the cave.

Frank (1973), in a study of flowstone layers in Australian caves, stresses the relationship between cessation of clastic deposition and the formation of flowstone, and the fact that the latter is not climate-dependent. It seems reasonable to regard the flowstone layers in Devil's Lair as marking sedimentation pauses, probably resulting from the temporary blocking of the cave entrances, rather than as intervals of warmer, wetter climatic conditions. However, bearing in mind the conclusions of Gams (1968), working on the Postojna cave, which provided additional support for the theory that a surface environment of high precipitation and dense vegetation is optimum for encouraging speleothems, it is worth considering in the case of Devil's Lair that an increase in local vegetation cover might be a contributory factor in flowstone formation, especially in the thick flowstone at the top of the deposit. This layer, visible for example at the top of the west face of Trench 5 (Dortch and Merrilees 1973, Fig. 5) was clearly deposited after 12 000 BP, before the deposition of the 'dark earthy' layer, 325 ± 85 BP, which originated through a different set of processes and via a different cave entrance. It seems likely that the processes responsible for the deposition of the main bulk of the clastic sediments became inoperative around 12 000 BP and that the sedimentation pattern of the cave was interrupted. After this time the thick band of flowstone was deposited and sedimentation then resumed, resulting in the 'dark earthy' layer which has a high humus content and seems largely to consist of redeposited topsoil. The depositional hiatus marked by this thick and very complex multiple flowstone was almost certainly caused by the blocking of the north entrance.

Diagenesis

The clastic cave sediments are characterised by their mostly inherited features which reflect previous depositional environments. Transport into the cave has had little influence on the sediments, but diagenesis, which to some extent reflects climate, has left some imprint. Diagenetic processes include lithification through carbonate cementation, the formation of gypsum deposits, movement of soil phosphates, humus and soluble salts, in addition to biogenic disturbance through, for instance, penetration of rootlets and human activity.

Human and animal activity

Human activity is evidenced principally by the disturbance of the deposits, for example by digging of pits and the remains of hearths, and by the addition of archaeological material, either artifacts or food debris.

Human groups entering the cave have also resulted in the addition of phosphates together with increments of humus and plant material from outside. Animal activity has proceeded along similar lines, again resulting in disturbance and also in waste breakdown products such as collophane.

Several lenses have been recognised as hearths on the basis of increased charcoal content and the presence of burnt bone. Examination of such hearth deposits under the microscope showed that the quartz sand grains were heavily coated with smaller particles, giving them a 'dusty' appearance, and that many agglomerations of cracked and burnt grains occurred. Modifications of grain surface texture included mazes of fine cracks, angular splitting and encrustations of charcoal. These microscopic characteristics reinforce the interpretation of hearths.

Lithification

The process of lithification of the sediments by the addition of calcitic cement is certainly the most important diagenetic process operating. This must be carefully distinguished from the formation of flowstone, since the calcite precipitation here occurs after the deposition of the clastics, the grains are smaller, crystal formations unclear and there are no defined boundaries between calcite cement and clastic grain. The cohesion imparted by this process has already been discussed. All the Devil's Lair deposits have been affected to some degree, and in some cases this has resulted in lithification. The chemical processes are, however, similar to those active in the formation of flowstone, namely the precipitation of calcite from solutions rich in carbon dioxide, but this occurs after the deposition of the clastics and is a continuing process.

Formation of gypsum

Minor deposits of gypsum are found within the deposits, frequently associated with rootlets and occurring in larger concentrations around roots and root holes. The finest rootlets are often completely coated in white gypsum, and occasionally moulds are left where roots have once been. Under normal weathering any sulphide present in bedrock is oxidised to sulphate, and in the course of soil formation the sulphate becomes available to plants and micro-organisms, and part of it is leached. Under temperate conditions and in well drained soils, the sulphur is present in organic matter, probably in amino acids such as cystine and cysteine, but most is removed by leaching. Under more arid conditions it is retained and often separates out as gypsum deposits. Oxidation of sulphides present in organic matter and plants is catalysed by the action of bacteria which make use of the energy released. Leaching is not an important process within these cave sediments. The gypsum deposits appear to have formed around the roots by the processes described above, and the movement of water within the cave sediment is not sufficient to disperse them.

Conclusions

In any study of this type it is important to relate the deposits to the morphology and bed rock of the cave, and in this case the latter is of paramount importance. The aeolianite in which the cave is developed has governed the formation and constituents of the sediments, and any other factors including climatic variations, human or animal activity, being of only secondary importance. The sequence of deposits is interesting because of extreme textural uniformity, seemingly independent of macroclimatic influences. The primary source of the cave sediments is undoubtedly weathering of the aeolianite, additional material being washed and blown in from outside, or brought in by animals or human groups visiting the cave. Flowstone formations, which constitute a substantial part of the sequence and are interleaved with the clastic sediments, are related to pauses in clastic sedimentation caused by blocking of the cave entrances. The cohesion of the deposits is effected by secondary accretion of calcium carbonate around the quartz sand grains, forming a cement. The deposits retain many of the features of previous stages in the depositional cycle, a situation completely contrary to that found in any of the limestone caves of the northern hemisphere. It is suggested that the sediments accumulated in intermittent bursts, perhaps related to episodes of increased rainfall.

Acknowledgements.—The writer gratefully acknowledges the award of a grant from the Australian Research Grants Committee which enabled her to visit the site, together with the invaluable assistance of Mr. C. E. Dortch and Dr. D. Merrilees. Help and criticism from Mr. A. Baynes, Dr. R. Frank and Dr. J. Jennings have also been beneficial. Laboratory and computing facilities were kindly provided by the Department of Archaeology, University of Southampton, and the Institute of Archaeology, University of Oxford.

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